Computer Aided Explosives Facility Site Planning and Analysis

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Background

US Air Force munitions present a considerable threat to critical personnel and material andcause significant operational restrictions on USAF bases in both peace and war. Reductions in the number of aircraft and people in the US Air Force amplify the operational impact of an explosion, whether caused by an accident or enemy action. Improving USAF operational capability by increasing available quantities of munitions, reducing operational restrictions, and reducing the threat presented by munitions is the goal of the USAF Explosives Hazard Reduction Program. Since it is unlikely that munitions in the USAF inventory will be replaced by munitions filled with insensitive high explosives in the foreseeable future, it is necessary to address the threats posed by inventory munitions as an integral part of operational readiness. To properly focus-hazard reduction efforts, one needs to know which munitions cause the greatest hazards / operational restrictions, and which technologies offer the greatest potential operational gains. Integrated Systems Analysts, Inc. was tasked by the USAF Explosives Hazard Reduction (EHR) Program Office to study several USAF bases, to quantify explosives hazards on those bases, recommend solutions to those hazards, and recommend technologies which should be included in the EHR Program. Quantification of various explosives options for an entire air base is an extremely complicated task and requires more than a ruler, safety tables, and a hand calculator to be accomplished in a reasonable amount of time. For example at Kunsan AB, ROK there were 1,291 facilities, of which, 222 were sited for explosives. This resulted in 40,320 building pairs which required analysis. Assuming an analysts could measure distances, apply all criteria for all hazard classes and perform analysis on each building pair in 10 minutes (a ridiculously short time) it would take 40,320 * 10 = 403,200 minutes = 6,720 manähours = 3.2 man years for the analysis alone. This is clearly a process which needs to be computerized. ISA developed a geographic information system (GIS) based spatial analysis approach to this problem. This system is based on the linking of a GIS and database and custom computer code developed to assist in mapping and analysis. This system is referred to as "Assessment System for Hazard Surveys" (ASHS). This system has been applied to three air bases and a fourth air base is being studied now. Additionally ASHS can be easily used for explosives facility siting.

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Introduction

ASHS is a combination of two commercial software programs, MapGrafix™ a Geographic Information System from ComGrafix, Inc. and 4th Dimension™ a relational database from ACI. A third commercial product 4D Draw™ a 4D drawing module from ACI is being integrated into ASHS to act as the display engine. These software programs currently work only on the Macintosh operating system, however, ACI has announced that 4D and 4D Draw will be released in a platform independent version "4D Universal" in 1995. This will permit ASHS to operate on most common operating systems. See attachment 1. Full implementation of 4D Draw will permit ASHS to be independent from GIS or CAD systems and operate strictly within 4D.

An overview of the current version of ASHS is shown in figure 1.

Figure 1. Overview of Current ASHS Structure

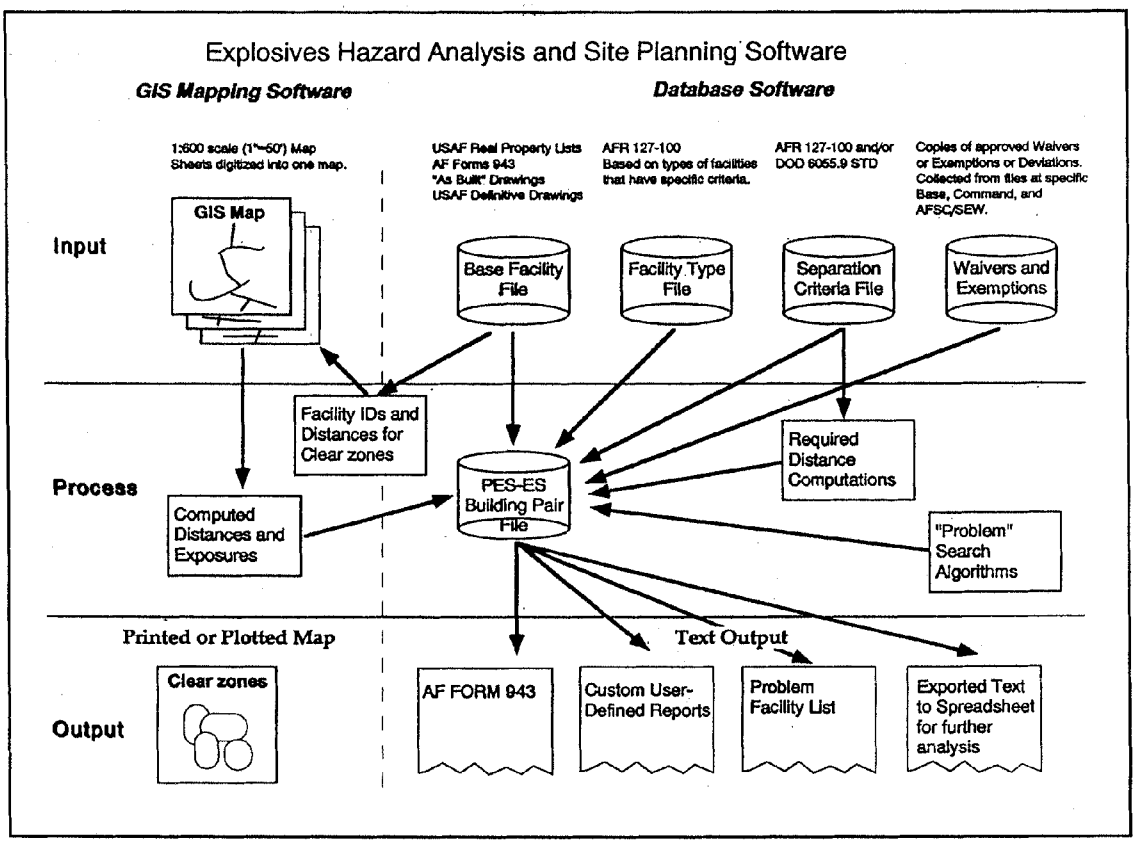


Figure 1. Overview of Current ASHS Structure

ASHSdynamically links the GIS and database so that the analyst can click on a map object and get information fromthe database regarding that object, or search the database and have the results of the search be reflected by highlighting objects on the map. This gives the analysts both the textural and graphic views of the problems. Powerful search, reporting, and drawing tools allow the analysts to quickly see the problems so solutions to them can be derived, print reports or results of analysis, and print or plot maps to accompany these reports. Additionally, ASHS will create the Air Force site planning forms (AF form 943) for the facilities selected by the analysts. Mapping One must know the distance between facilities to determine the effects of an explosion in one facility on another. Maps must be developed which are accurate and contain all appropriate map objects. In MapGrafix all features drawn on the map are considered map objects. These objects may be assigned an identification number (ID) and this ID is then used to link the map object with a database object as shown in figure 2. In ASHS we use object IDs which make sense to the analysts, for example a munitions storage Igloo with building number 1395 would have an ID of 1395gIGL, 1295PL would be a parking lot for facility 1295.

Figure 2. Linking of Map and Database

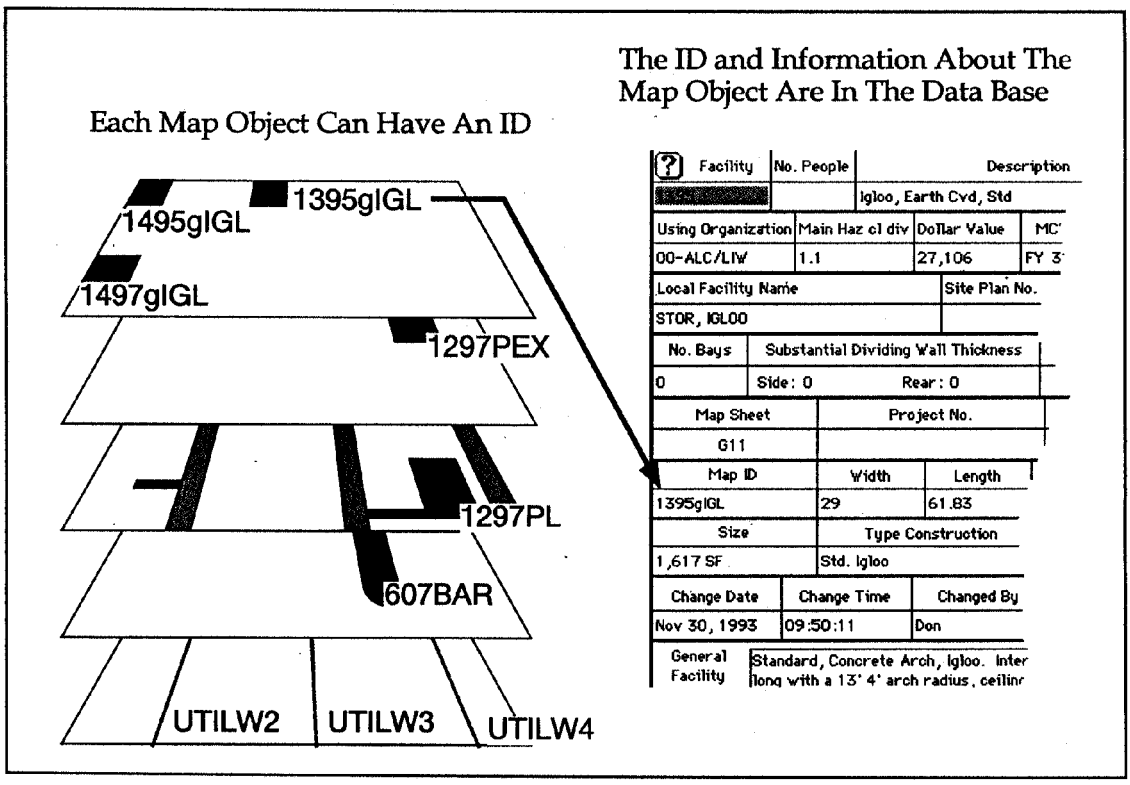


Figure 2. Linking of Map and Database

Maps can be created in layers. MapGrafix supports 500 layers. The analysts can use layers to separate various types of map objects, for example, igloos on one layer, future construction on another, and roads on yet another, and so on.

The analysts can turn on (make visible) or turn off (make invisible) any combination of these layers. This selective view allows the analysts to reduce screen clutter and focus on problems at hand.

Where does the map come from? We use maps which are hand digitized, maps imported in various electronic formats such as Intergraph, DXF, etc.. Hand digitizing is done by placing a map or photo of known scale on a digitizing table, informing the GIS of the scale, identifying known coordinates (benchmarks), then clicking on the corners of each map object, or in case of a curved object like a stream bed, clicking along its path as shown in figure 3.

Figure 3. Creating Map Objects

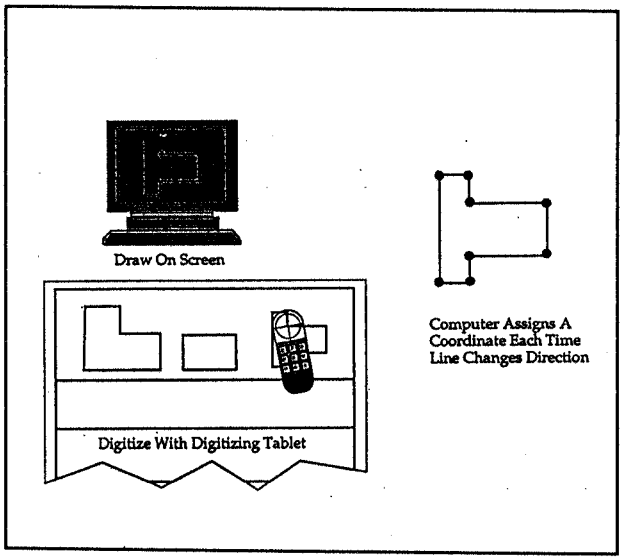


Figure 3. Creating Map Objects

If three known coordinates are identified, the GIS can assign geographic coordinates to each map object. The GIS will detect flaws in the maps such as stretching, shrinking, and distortions caused by moisture, or by reproduction, and correct them in a process called "rubber sheeting" (figure 4).

Figure 4. Rubber Sheeting

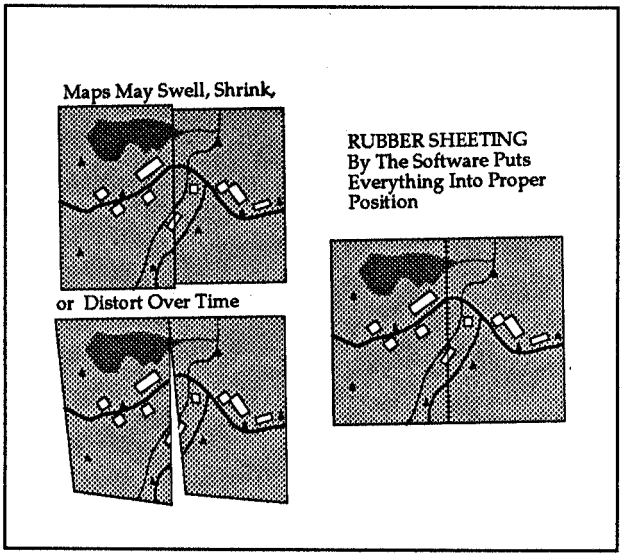


Figure 4. Rubber Sheeting

We have developed special drawing tools (figure 5) to speed map creation. These tools allow us to accurately draw specially shaped buildings we encounter frequently such as hardened aircraft shelters, munitions igloos, etc. There are a variety of tools to manipulate graphic objects, create annotation, and create map objects from typed in survey data.

Figure 5. Special Tools Speed Map Creation

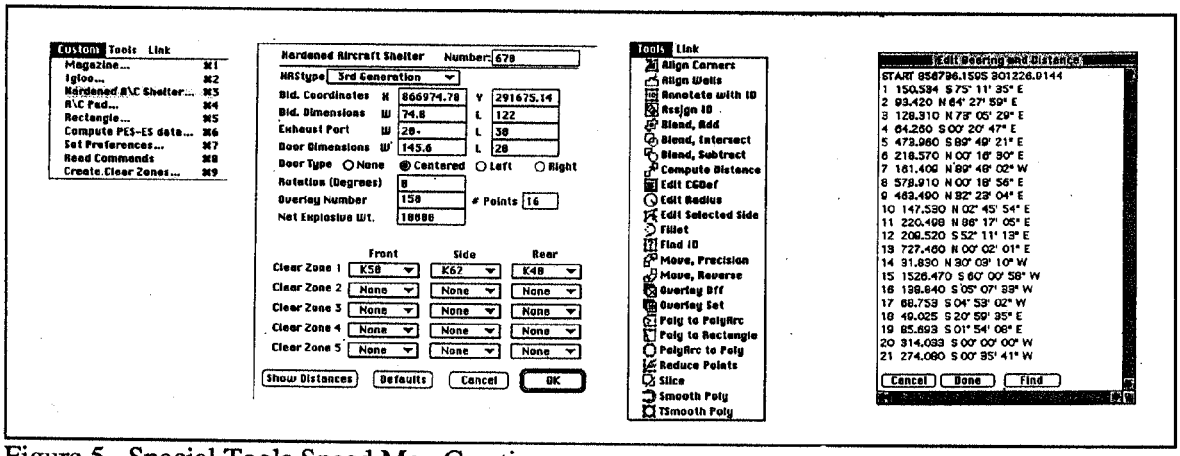


Figure 5. Special Tools Speed Map Creation

The GIS contains the coordinates of the corners of each map object and can accurately calculate the distances between map objects using special ISA built algorithms. Algorithms also had to be developed to determine if facilities were barricaded and for facilities having segmented clear zones (different separation factors required for front, side, and rear)[1]. The GIS creates a file containing the distances between each building pair and provides this to the database.

Database

The database is the analytical engine for ASHS. Four relational files are used to derive the data which drives the analytical engine. Two of these, the Facility Type File, and Separation Criteria File, contain criteria and are already in the database since these do not change from base to base. The remaining files, the Base Facility File, and the Waivers and Exemptions File are completed by the user for each specific base. Fortunately much of this information can be electronically imported from base civil engineering records. The database uses this information along with separation data from the map to automatically derive all other database files used in the analysis. Figure 6 illustrates facility information for a single facility derived from several related files.

Figure 6. Facility Data for One Facility

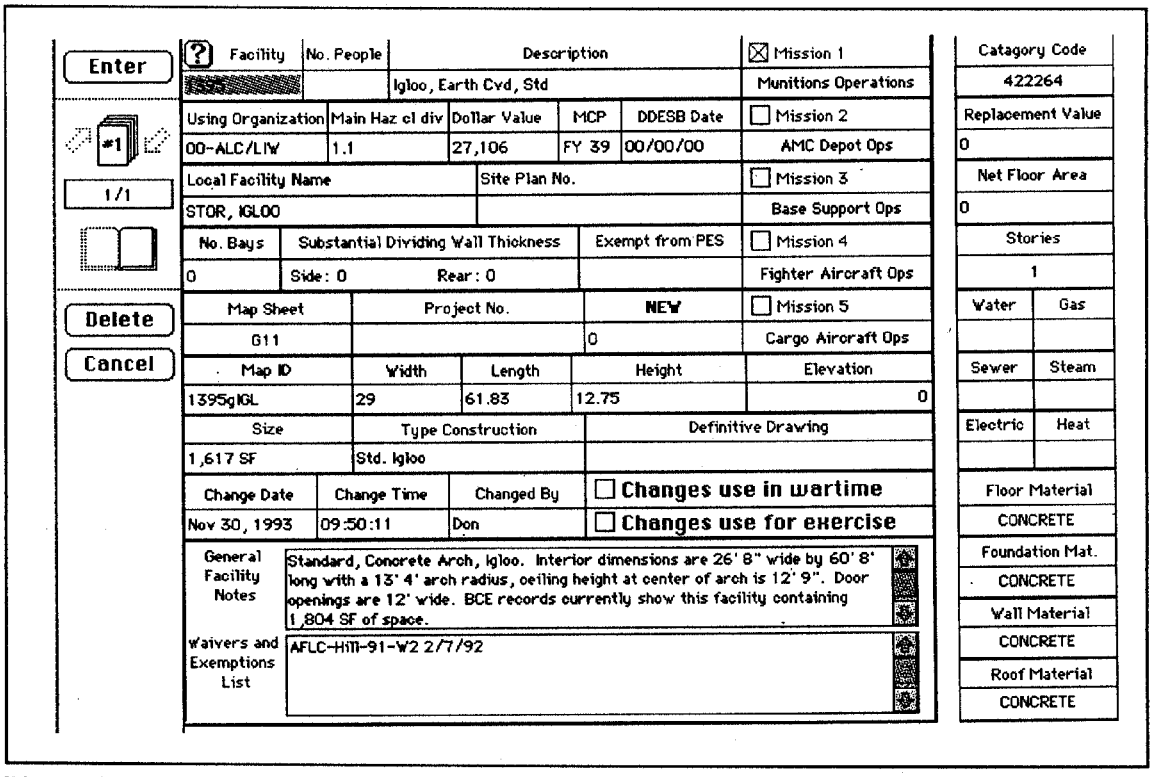


Figure 6. Facility Data for One Facility

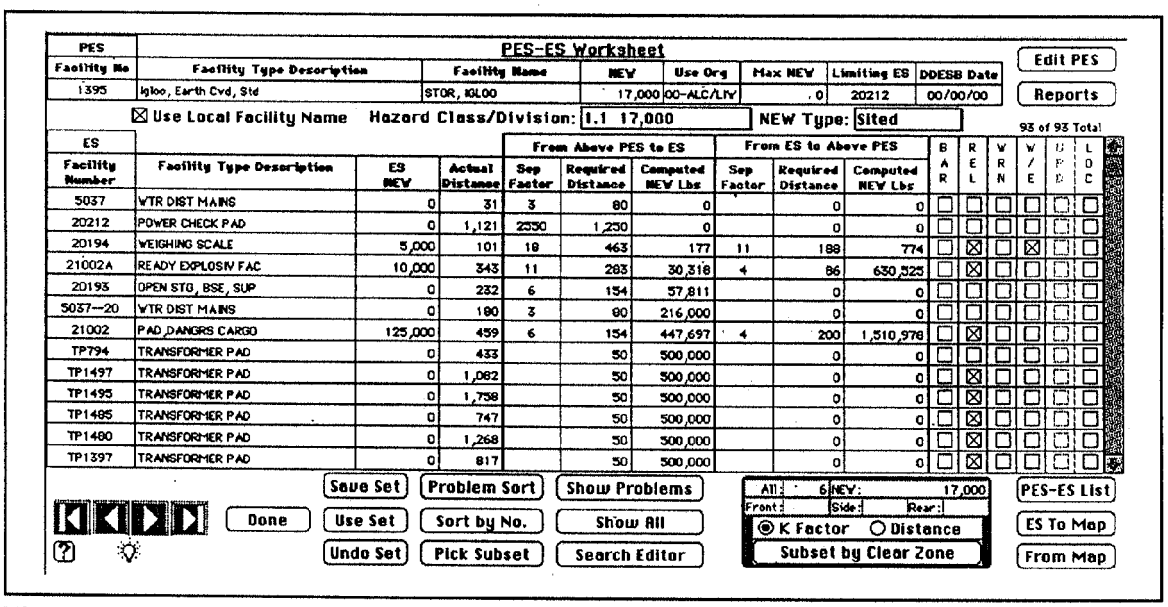
Analysis

The primary analytical tool, the PES-ES worksheet uses information completely derived by the database and map. This worksheet (figure 7) shows all exposed sites (ES) to a Potential Explosion Site (PES). The analysts can examine each PES in great detail to determine which ES restrict the PES. In this view the "computed NEW" has been sorted in increasing order using the "Sort Problems" button. This brings the most restrictive exposures for the PES to the top of the list. The analysts can easily determine which ESs restrict the PES by looking at the "computed NEW" which reflects the quantity of munitions which can be legally stored with the criteria is applied for each ES. The analyst can select one or more facilities by clicking on them and highlight them on the map by clicking the ES to map button.

Other features are built in to assist the user, such as, pull down menus to give views of various hazard classifications and three tiered siting, the digital assistant “Light bulb Icon” which brings up “Newton” who will help the analysts by analyzing the displayed data and asking / answering ten or so of the most frequently asked questions.

The help screen “?” icon allows the user to click on and get information regarding each of the features on the current screen.

Figure 7. PES-ES Worksheet



PES Facility No	Facility Type Description	Facility Name	NEW	Use Org	Max NEW	Limiting ES	DDESB Date
1395	Igloo, Earth Cvd, Std	STOR, IGLOO	17,000	00-ALC/LIV	0	20212	00/00/00

ES Facility Number	Facility Type Description	ES NEW	Actual Distance	From Above PES to ES: Sep Factor	Required Distance	Computed NEW Lbs	From ES to Above PES: Sep Factor	Required Distance	Computed NEW Lbs	B A R	R E L	W R N	W / E	D F D	L D C
5037	WTR DIST MAINS	0	31	3	80	0		0	0	☐	☐	☐	☐	☐	☐
20212	POWER CHECK PAD	0	1,121	2330	1,230	0		0	0	☐	☐	☐	☐	☐	☐
20194	WEIGHING SCALE	5,000	101	18	463	177	11	188	774	☐	☒	☐	☒	☐	☐
21002A	READY EXPLOSIV FAC	10,000	343	11	283	30,318	4	86	630,525	☐	☒	☐	☐	☐	☐
20193	OPEN STG, BSE, SUP	0	232	6	154	57,811		0	0	☐	☐	☐	☐	☐	☐
5037--20	WTR DIST MAINS	0	180	3	80	216,000		0	0	☐	☐	☐	☐	☐	☐
21002	PAD,DANGRS CARGO	125,000	459	6	154	447,697	4	200	1,510,978	☐	☒	☐	☐	☐	☐
TP794	TRANSFORMER PAD	0	433		50	500,000		0	0	☐	☐	☐	☐	☐	☐
TP1497	TRANSFORMER PAD	0	1,082		50	500,000		0	0	☐	☒	☐	☐	☐	☐
TP1495	TRANSFORMER PAD	0	1,758		50	500,000		0	0	☐	☒	☐	☐	☐	☐
TP1485	TRANSFORMER PAD	0	747		50	500,000		0	0	☐	☒	☐	☐	☐	☐
TP1480	TRANSFORMER PAD	0	1,268		50	500,000		0	0	☐	☒	☐	☐	☐	☐
TP1397	TRANSFORMER PAD	0	817		50	500,000		0	0	☐	☒	☐	☐	☐	☐

Figure 7. PES-ES Worksheet

If the analysts wants detailed information regarding a specific building pair, the Detailed PES-ES worksheet (figure 8) can be selected by doubleäclicking on a line in the PES-ES Worksheet containing the ES. This worksheet contains extensive information regarding this

building pair. Information in other databases, such as waivers and exemptions , notes, and criteria, can be consulted directly by clicking on the appropriate button on the worksheet

Figure 8. Detailed PES-ES Worksheet

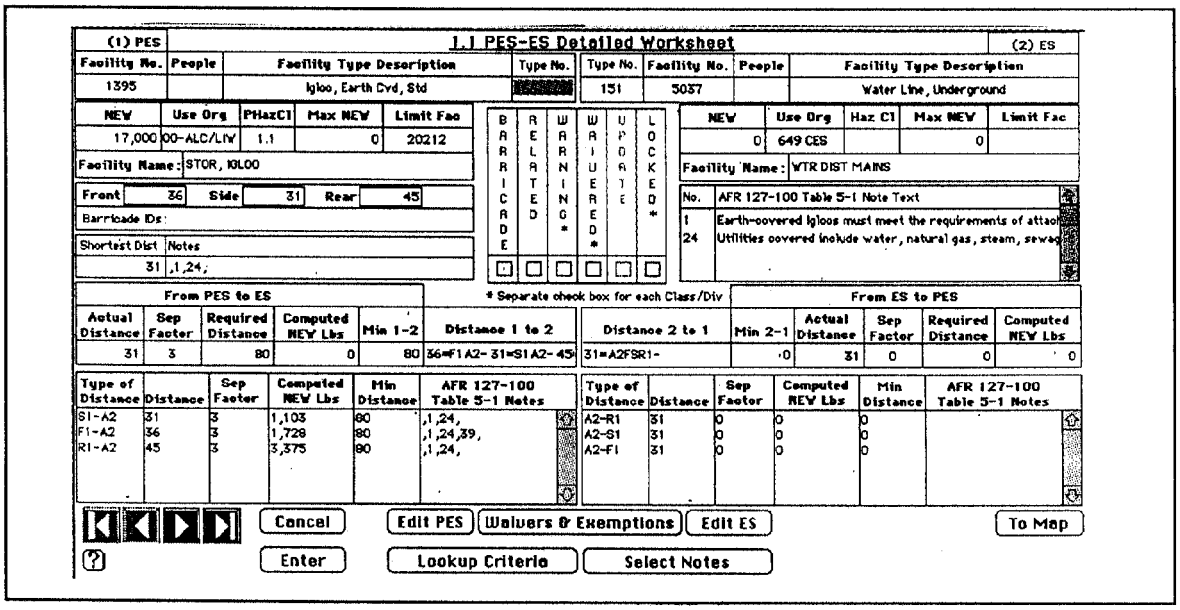
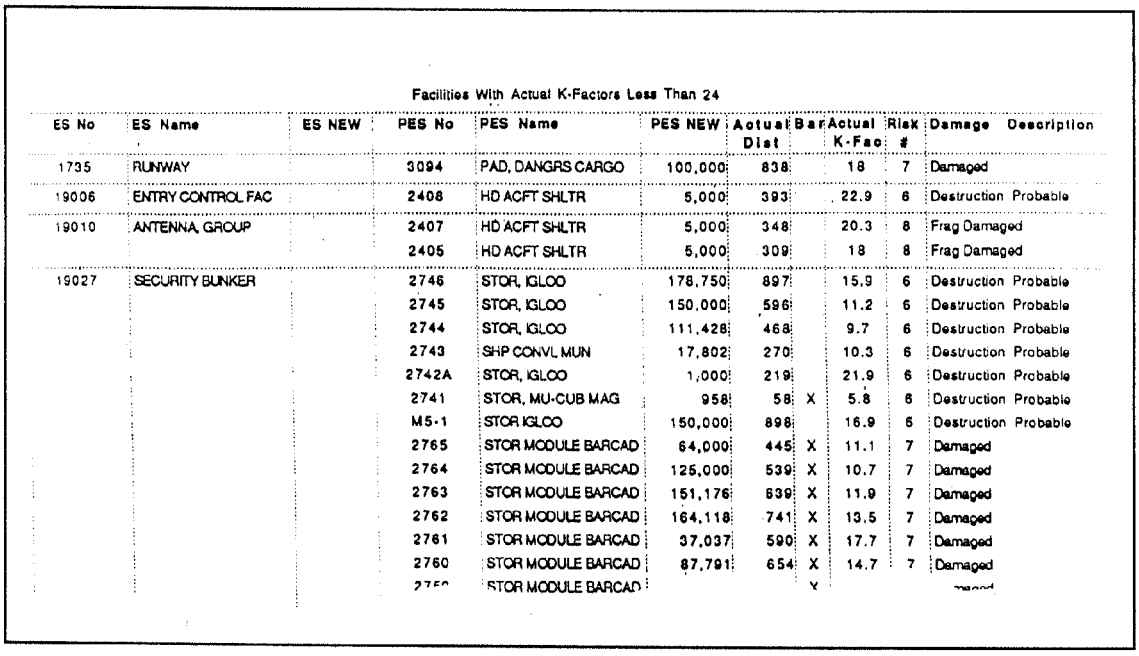


Figure 8. Detailed PES-ES worksheet

Risk Assessment

A general risk assessment, based upon the construction of the ES , the facility type, and the explosives loading of the PES, is generated by the database (figure 9). This assessment defines the risk to each ES posed by each PES. This assessment allows the Wing Commander or Higher Headquarters to prioritize actions taken to correct these hazards.

Figure 9. Risk Assessment Listing



Facilities With Actual K-Factors Less Than 24

ES No	ES Name	ES NEW	PES No	PES Name	PES NEW	Actual Dist	Bar	Actual K-Fac	Risk #	Damage Description
1735	RUNWAY		3094	PAD, DANGRS CARGO	100,000	838		18	7	Damaged
19006	ENTRY CONTROL FAC		2408	HD ACFT SHLTR	5,000	393		22.9	6	Destruction Probable
19010	ANTENNA, GROUP		2407	HD ACFT SHLTR	5,000	348		20.3	8	Frag Damaged
			2405	HD ACFT SHLTR	5,000	309		18	8	Frag Damaged
19027	SECURITY BUNKER		2746	STOR, IGLOO	178,750	897		15.9	6	Destruction Probable
			2745	STOR, IGLOO	150,000	596		11.2	6	Destruction Probable
			2744	STOR, IGLOO	111,428	468		9.7	6	Destruction Probable
			2743	SHP CONVL MUN	17,802	270		10.3	6	Destruction Probable
			2742A	STOR, IGLOO	1,000	219		21.9	6	Destruction Probable
			2741	STOR, MU-CUB MAG	958	58	X	5.8	6	Destruction Probable
			M5-1	STOR IGLOO	150,000	898		16.9	6	Destruction Probable
			2765	STOR MODULE BARCAD	64,000	445	X	11.1	7	Damaged
			2764	STOR MODULE BARCAD	125,000	539	X	10.7	7	Damaged
			2763	STOR MODULE BARCAD	151,176	639	X	11.9	7	Damaged
			2762	STOR MODULE BARCAD	164,118	741	X	13.5	7	Damaged
			2761	STOR MODULE BARCAD	37,037	590	X	17.7	7	Damaged
			2760	STOR MODULE BARCAD	87,791	654	X	14.7	7	Damaged
			2759	STOR MODULE BARCAD			X			

Figure 9. Risk Assessment Listing

Reports

Reports are provided to the Wing Commander at each base surveyed. These reports provide an executive summary describing the most serious hazards discovered and recommended corrective actions, both long term and short term. The main body of the report is a facility by facility discussion of problems / restrictions to and from the facility and recommended corrective actions for them. The report also contains the risk assessment for each exposed facility. Problems which need to be addressed by the EHR program are identified and the mission impact caused by these problems is quantified. Both the electronic map and database generated for this analysis are available to the base.

Results of Analysis

Analysis of three bases have revealed a large variety of problems. Many problems were the result of the poor quality maps available to the original site planner. Maps available to the site planner often do not show vital utilities, fuel tanks, and other objects to which criteria apply, they may be out of date, depicting facilities which no longer exist or not depicting new facilities. Some maps were inaccurately drawn for example an extension added to one base was rotated 20° from its actual location.

Problems were quickly identified by the "Show Problems" feature. These have been

quantified for each base and for the composite of all bases surveyed. Some of the major problems have been tackled by the EHR program and others await funding. Third generation hardened aircraft shelter clear zones have been significantly reduced for explosives weights of 1,000 pounds or less. A new, less expensive, modular, munitions storage facility, the Munitions Storage Module, has been designed, tested and should receive DDESB certification as a standard Igloo in the near future. Fourteen hundred foot fragment clear zones required for CBUä87 munitions are driven by a faulty test protocol, these are scheduled to be reätested with the expectation that these clear zones will also be significantly reduced. And a new container designed for 40 mm Grenades provides a hazard classification of C/D 1.2 allowing them to be stored in armories where needed. Several other programs await action such as wingätoäwing propagation of explosions on aircraft, safe missile separation distances, barrier designs, and others.

Conclusion

ASHS is a proven tool for explosives facility site planning and analysis. It has demonstrated its usefulness during analysis of three bases and site planning assistance to requesting organizations. The spatial analysis features of ASHS make it useful for other types of analysis such as environmental concerns. Continuing development improves both the user interface and the speed of execution. The release of 4D universal will make this a true multiäplatform analytical tool.

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1. Becker, Larry D. and Jenus, Joseph Jr., "A Geographic Information System (GIS) for Explosives Facility Siting Analysis", Minutes of the 25th DOD Explosives Safety Seminar, August 1992.